

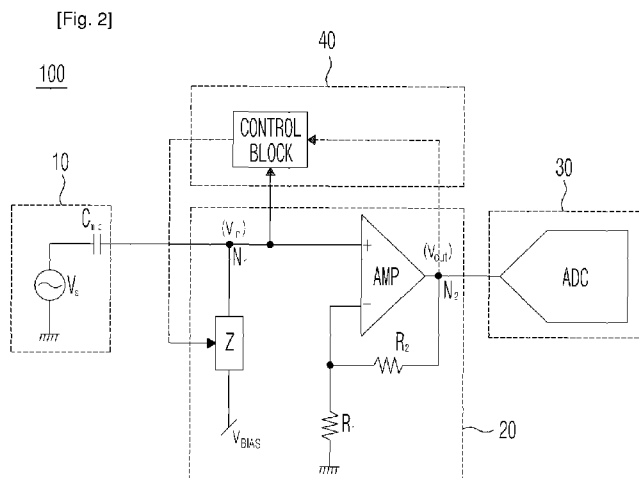


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(54) Title: DIGITAL CONDENSER MICROPHONE HAVING PREAMPLIFIER WITH VARIABLE INPUT IMPEDANCE AND METHOD OF CONTROLLING VARIABLE INPUT IMPEDANCE OF PREAMPLIFIER



(57) Abstract: The present invention provides a digital condenser microphone having a preamplifier with variable input impedance and a method of controlling the variable input impedance of the preamplifier. The preamplifier includes a bias terminal (Bias) for applying a bias voltage to an input signal when the input signal is output from a microphone condenser. An impedance unit (Z) includes at least one variable input impedance element which is connected to the bias terminal and to which the bias voltage is applied via the bias terminal. An operational amplifier receives the input signal, converts the input signal into an output signal, and outputs the output signal. A control block (40) determines whether a DC voltage level of the output signal output from the operational amplifier has reached a reference value, and controls a total impedance of the impedance unit based on a result of the determination.

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Description

Title of Invention: DIGITAL CONDENSER MICROPHONE HAVING PREAMPLIFIER WITH VARIABLE INPUT IMPEDANCE AND METHOD OF CONTROLLING VARIABLE INPUT IMPEDANCE OF PREAMPLIFIER

Technical Field

- [1] The present invention relates, in general, to a digital condenser microphone and, more particularly, to a digital condenser microphone having a preamplifier with variable input impedance and a method of controlling the variable input impedance of the preamplifier.

Background Art

- [2] Generally, condenser microphones are parts that convert the sound pressure of externally input acoustic signals into a voltage signal. One such condenser microphone is a digital condenser microphone (Electret Condenser Microphone: ECM) which is characterized in that an existing post-processing stage is remarkably simplified and the noise interference of analog signals is eliminated. However, such a digital condenser microphone must be essentially provided with a preamplifier for amplifying input signals and eliminating noise from the input signals because detection sensitivity to externally input acoustic signals is low. In particular, in recent condenser microphones, as condensers are gradually becoming small in size and integrated, active capacitance (typically, about 1 pF to 10 pF) greatly decreases, and then drop in sensitivity is greater.
- [3] FIG. 1 is a circuit diagram showing a conventional digital condenser microphone.
- [4] Referring to FIG. 1, the conventional digital condenser microphone includes a microphone sensor unit 1, a high-impedance interface unit 2, a Direct Current (DC) cut-off condenser 3, a preamplifier 4, and an Analog to Digital (A/D) converter 5.
- [5] The microphone sensor unit 1 includes an input power source V_s and a condenser C_{mic} for a microphone, and is configured to detect an acoustic signal V_s from the outside of the microphone and output the detected acoustic signal as a voltage V_1 .
- [6] The high-impedance interface unit 2 includes a resistor R_1 having a high-input impedance at the input terminal of a Junction gate Field-Effect Transistor (JFET). The high-impedance interface unit 2 receives the voltage V_1 output from the microphone sensor unit 1 and then outputs a voltage V_2 via current control.
- [7] The DC voltage cut-off condenser 3 cuts off a DC voltage and only an acoustic signal is converted into current by a resistor R_2 .

- [8] The acoustic signal is converted into the current by the resistors R_2 and R_4 of the preamplifier 4 and is output as a voltage V_3 by resistors R_3 and R_5 in a subsequent stage, and the voltage V_3 is input to the A/D converter 5. In this case, the gain of the preamplifier 4 is determined by $R_3/R_2 (R_5/R_4)$.
- [9] As described above, the conventional preamplifier is configured such that the input voltage V_1 undergoes several stages of voltage/current and current/voltage conversion via the impedance interface unit 2 and the input resistors R_2 and R_4 of the preamplifier 4 and then the amplified voltage signal V_3 is output.
- [10] However, the conventional digital condenser microphone in which the preamplifier is implemented using the JFET is vulnerable to noise generated by the input power source. Further, disadvantages of the conventional digital condenser microphone are that it requires an individual element, such as the JFET, and that it is inappropriate to integrate the microphone interface, the preamplifier, and the A/D converter into a single chip due to an increase in area attributable to the high-impedance resistor at the input terminal and the DC voltage cut-off condenser.

Disclosure of Invention

Technical Problem

- [11] Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to provide a digital condenser microphone having a preamplifier with variable input impedance and a method of controlling the variable input impedance of the preamplifier.

Solution to Problem

- [12] In accordance with an aspect of the present invention, there is provided a preamplifier for a digital condenser microphone, including a bias terminal for applying a bias voltage to an input signal when the input signal is output from a microphone condenser, an impedance unit including at least one variable input impedance element which is connected to the bias terminal and to which the bias voltage is applied via the bias terminal, an operational amplifier for receiving the input signal, converting the input signal into an output signal, and outputting the output signal, and a control block for determining whether a Direct Current (DC) voltage level of the output signal output from the operational amplifier has reached a reference value, and controlling a total impedance of the impedance unit based on a result of the determination.
- [13] In accordance with another aspect of the present invention, there is provided a digital condenser microphone including a preamplifier provided with a bias terminal for applying a bias voltage to an input signal when the input signal is output from a microphone condenser, an impedance unit including at least one variable input impedance element which is connected to the bias terminal and to which the bias voltage is

applied via the bias terminal, an operational amplifier for receiving the input signal, converting the input signal into an output signal, and outputting the output signal, and a control block for determining whether a Direct Current (DC) voltage level of the output signal output from the operational amplifier has reached a reference value, and controlling a total impedance of the impedance unit based on a result of the determination, a microphone sensor unit provided with the microphone condenser and configured to convert an externally input acoustic signal into the input signal using the microphone condenser and output the input signal to the preamplifier, and an Analog to Digital (A/D) converter configured to receive an output signal from the preamplifier and convert the output signal into a digital signal.

- [14] In accordance with a further aspect of the present invention, there is provided a method of controlling a variable input impedance of a preamplifier for a digital condenser microphone, including detecting a Direct Current (DC) voltage level of an output signal output from an operational amplifier, determining whether the DC voltage level has reached a reference value, and if the DC voltage level has not reached the reference value, sequentially one by one turning on switches being in an OFF state, among a plurality of switches respectively corresponding to a plurality of transistors included in an impedance unit.

Advantageous Effects of Invention

- [15] In accordance with the present invention, there can be provided a digital condenser microphone having a preamplifier with variable input impedance and a method of controlling the variable input impedance of the preamplifier.
- [16] In accordance with the present invention, the total impedance of an impedance unit is controlled, so that the DC voltage level of an input signal output from a microphone sensor unit can rapidly converge on an operating region.
- [17] Further, after the input signal has converged on the operating region, the total impedance of the impedance unit is increased, thus enabling the DC voltage level and the sensitivity of the input signal to be kept constant.
- [18] Furthermore, since the preamplifier of the digital condenser microphone according to the present invention has a compact structure, thermal noise generated by transistors can be reduced. Furthermore, since the preamplifier uses a correction circuit having a feedback structure for adjusting the voltage level of the input signal using the voltage level of the output signal, the start-up time caused by the input impedance can be shortened.

Brief Description of Drawings

- [19] FIG. 1 is a circuit diagram showing a conventional digital condenser microphone;
- [20] FIG. 2 is a diagram showing the schematic construction of a digital condenser mi-

crophone according to an embodiment of the present invention;

[21] FIG. 3 is a diagram showing in detail the impedance of the digital condenser microphone of FIG. 2; and

[22] FIG. 4 is a flowchart showing an impedance control method performed by the control block of FIG. 3.

Best Mode for Carrying out the Invention

[23] The present invention may make various changes and have various forms, and specific embodiments will be illustrated in drawings and will be described in detail in the present specification. However, these are not intended to limit the present invention to specific disclosure forms, and it should be understood that the present invention includes all changes, equivalents, or substitutions falling within the spirit and scope of the present invention.

[24] The terms such as "first" and "second" may be used to describe various components, but those components should not be limited by the terms. The terms are merely used to distinguish one component from other components, and a first component may be designated as a second component and a second component may be designated as a first component in a similar manner, without departing from the scope of the present invention.

[25] The terms used in the present specification are merely used to describe specific embodiments and are not intended to limit the present invention. A singular expression includes a plural expression unless a description to the contrary is specifically made in context. In the present specification, it should be understood that such terms as "include" or "have" are merely intended to indicate that features, numbers, steps, operations, components, parts, or combinations thereof are present, and are not intended to exclude a possibility that one or more other features, numbers, steps, operations, components, parts, or combinations thereof will be present or added.

[26] Unless differently defined, all terms used here including technical or scientific terms have the same meanings as the terms generally understood by those skilled in the art to which the present invention pertains.

[27] The terms identical to those defined in generally used dictionaries should be interpreted as having meanings identical to contextual meanings of the related art, and are not interpreted as being ideal or excessively formal meanings unless they are definitely defined in the present specification.

[28] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings.

[29] FIG. 2 is a diagram showing the schematic construction of a digital condenser microphone according to an embodiment of the present invention.

- [30] Referring to FIG. 2, a digital condenser microphone 100 includes a microphone sensor unit 10, a preamplifier 20, an Analog to Digital Converter (A/D converter) 30, and a control block 40.
- [31] The microphone sensor unit 10 includes an external signal V_s and a condenser C_{mic} for a microphone (hereinafter referred to as a "microphone condenser C_{mic} "). The external signal V_s may be an externally input signal, that is, an audio signal or an acoustic signal that can be collected and combined from the outside of the digital condenser microphone 100. The external signal V_s refers to an electrical signal caused by vibrations that occur due to an audio signal or an acoustic signal when the audio signal or the acoustic signal is received using the digital condenser microphone 100.
- [32] When the external signal V_s is applied to the microphone condenser C_{mic} , the capacitance of the microphone condenser C_{mic} changes according to the sound pressure of the external signal V_s . An input signal V_{in} is a signal generated while the capacitance of the microphone condenser C_{mic} changes according to the sound pressure of the external signal V_s .
- [33] According to an embodiment, the microphone sensor unit 10 may be a sensor implemented as an individual element using an electret, or may be implemented as a condenser-type silicon Micro Electro Mechanical System (MEMS) microphone integrated into a semiconductor substrate.
- [34] The preamplifier 20 includes an impedance unit Z , a bias terminal Bias, and an operational amplifier Amp.
- [35] The impedance unit Z is a high-impedance element, and a bias voltage V_{BIAS} is applied to the impedance unit Z via the bias terminal Bias. The impedance unit Z is at least one variable input impedance element, and the total impedance of the impedance unit Z is controlled by the control block 40. In an embodiment, the impedance unit Z may be a variable input impedance element which is an active element.
- [36] The bias terminal Bias applies the bias voltage V_{BIAS} that is a DC voltage to the input signal V_{in} that is input to the operational amplifier Amp. The input signal V_{in} is a voltage output from the microphone sensor unit 10 and is detected at a first node N_1 . The input signal V_{in} is input to the operational amplifier Amp and is converted into current by a resistor R_1 . The current is output as an output signal V_{out} by a resistor R_2 in a subsequent stage, and the output signal V_{out} is input to the A/D converter 30. In this case, the gain of the operational amplifier Amp may be determined by $1+(R_2/R_1)$.
- [37] The operational amplifier Amp may be implemented in a mixed form of a folded-cascode structure and a two-stage structure so as to increase the gain. Further, according to an embodiment, the operational amplifier Amp may be implemented in a single output structure in which a common-mode feedback circuit is omitted in order to reduce the number of transistors included in the operational amplifier Amp.

- [38] The A/D converter 30 may be implemented as a delta-sigma modulator. Further, the delta-sigma modulator may be implemented as a switched capacitor or a continuous-time structure.
- [39] The control block 40 controls the total impedance of the impedance unit Z. In the early stage of operation of the digital condenser microphone 100, the control block 40 activates the bias terminal Bias within a short period of time by decreasing the total impedance of the impedance unit Z, thus enabling the bias voltage V_{BIAS} to be applied to the input signal V_{in} . Further, if the bias terminal Bias has already been activated, the control block 40 maintains the bias voltage V_{BIAS} applied to the input signal V_{in} by increasing the total impedance of the impedance unit Z. Accordingly, the input signal V_{in} that is input to the operational amplifier Amp may be transferred unchanged to the A/D converter 30.
- [40] In the present embodiment, the preamplifier 20 and the control block 40 are described as being separately implemented, but, in other embodiments, the control block 40 may be included in the preamplifier 20.
- [41] FIG. 3 is a diagram showing in detail the impedance unit of the digital condenser microphone of FIG. 2.
- [42] The impedance unit Z of the digital condenser microphone 100 may include a plurality of transistors Tr_1, Tr_2, \dots, Tr_n and a plurality of switches SW_1, SW_2, \dots, SW_n connected in a one-to-one correspondence with the transistors Tr_1, Tr_2, \dots, Tr_n . In this case, the transistors Tr_1 to Tr_n and the switches SW_1 to SW_n are connected in series with each other. For example, the first transistor Tr_1 and the first switch SW_1 are connected in series with each other, and the second transistor Tr_2 and the second switch SW_2 are connected in series with each other.
- [43] Further, the transistors Tr_1 to Tr_n are connected in parallel with one another. The switches SW_1 to SW_n are also connected in parallel with one another, similarly to the transistors Tr_1 to Tr_n . For example, the first transistor Tr_1 and the first switch SW_1 are connected in series, but the first and second transistors Tr_1 and Tr_2 are connected in parallel and the first and second switches SW_1 and SW_2 are connected in parallel.
- [44] In the present embodiment, the transistors Tr_1 to Tr_n and the switches SW_1 to SW_n respectively corresponding to the transistors Tr_1 to Tr_n function as a variable resistor. As shown in FIG. 2, the impedance unit Z is connected in series with the bias terminal Bias and the bias voltage V_{BIAS} is applied to the impedance unit Z. That is, the bias voltage V_{BIAS} is applied both to the transistors Tr_1 to Tr_n and to the switches SW_1 to SW_n respectively corresponding thereto. Each of the switches SW_1 to SW_n may function to turn on/off a connection between a corresponding one of the transistors Tr_1 to Tr_n connected in series with the switches SW_1 to SW_n and the bias terminal Bias.
- [45] The digital condenser microphone 100 according to the present embodiment

decreases the total impedance of the impedance unit Z to activate the microphone sensor unit 10. In the state in which the bias voltage V_{BIAS} is applied via the bias terminal Bias, as the number of switches SW_1 to SW_n being in an ON state, among the plurality of switches SW_1 to SW_n , is larger, the total impedance of the impedance unit Z becomes lower.

- [46] When the total impedance of the impedance unit Z becomes lower, the DC voltage level of the input signal V_{in} can rapidly converge on an operating region. That is, the voltage level of the input signal V_{in} transferred from the microphone sensor unit 10 of the digital condenser microphone 100 reaches the bias voltage V_{BIAS} , thus enabling the input signal V_{in} to be rapidly and effectively transferred to the A/D converter 30.
- [47] After the input signal V_{in} has converged on the operating region, the digital condenser microphone 100 increases the total impedance of the impedance unit Z. In the state in which the bias voltage V_{BIAS} has been applied via the bias terminal Bias, as the number of switches SW_1 to SW_n being in an OFF state among the plurality of switches SW_1 to SW_n is larger, the total impedance of the impedance unit Z becomes higher, and the impedance unit Z may have a total impedance of several gigaohms (G??).
- [48] When the total impedance of the impedance unit Z approximates several gigaohms, current leaked through the impedance unit Z becomes considerably small, so that the DC voltage level of the input signal V_{in} can be kept constant.
- [49] As described above, the number of switches being in an ON state, among the plurality of switches SW_1 to SW_n included in the impedance unit Z, is inversely proportional to the total impedance of the impedance unit Z. Further, in the present embodiment, the plurality of transistors Tr_1 to Tr_n included in the impedance unit Z may be transistors Tr_1 to Tr_n having the same characteristics. Similarly, the plurality of switches SW_1 to SW_n included in the impedance unit Z may be switches SW_1 to SW_n having the same characteristics.
- [50] The control block 40 controls the total impedance of the impedance unit Z by controlling the ON/OFF operations of the respective switches SW_1 to SW_n included in the impedance unit Z. The control block 40 determines whether to turn on or off the plurality of switches SW_1 to SW_n on the basis of the level of the output signal V_{out} output from the operational amplifier Amp.
- [51] The digital condenser microphone according to the present embodiment may further include a level detection unit 45 to measure the level of the output signal V_{out} output from the operational amplifier Amp. The level detection unit 45 detects the level of the voltage output from the operational amplifier Amp, that is, the DC voltage level of the output signal V_{out} at a second node N_2 , and transfers the detected DC voltage level to the control block 40.
- [52] The control block 40 may determine the DC voltage level of the input signal V_{in} on

the basis of the DC voltage level of the output signal V_{out} . In this case, the DC voltage level that is a reference value may be a bias voltage V_{BIAS} at which the input signal V_{in} converges on the operating region. If the DC voltage level of the input signal V_{in} has not reached the reference value V_{BIAS} , that is, when the DC voltage level of the input signal V_{in} is less than the reference value V_{BIAS} , the control block 4 decreases the total impedance of the impedance unit Z by sequentially turning on the switches SW_1 to SW_n of the impedance unit Z one by one. That is, the total impedance of the impedance unit Z gradually decreases by sequentially turning on the switches SW_1 to SW_n of the impedance unit Z .

- [53] In contrast, when the DC voltage level of the input signal V_{in} reaches the reference value V_{BIAS} , that is, when the DC voltage level of the input signal V_{in} is the reference value V_{BIAS} , the control block 4 may increase the total impedance of the impedance unit Z by turning off the switches SW_1 to SW_n of the impedance unit Z . When the switches SW_1 to SW_n of the impedance unit Z are turned off, the input impedance, that is, the total impedance of the impedance unit Z , increases, so that the DC voltage level of the input signal V_{in} may be kept constant.
- [54] In an embodiment, when the DC voltage level of the input signal V_{in} is the reference value V_{BIAS} , the control block 40 may sequentially turn off the switches SW_1 to SW_n of the impedance unit Z one by one.
- [55] Although, in the present embodiment, the control block 40 and the level detection unit 45 have been described as being separately implemented, the level detection unit 45 may be included in the control block 40 in other embodiments.
- [56] FIG. 4 is a flowchart showing an impedance control method performed by the control block of FIG. 3.
- [57] Referring to FIG. 4, the control block 40 receives the DC voltage level of the output signal V_{out} from the level detection unit 45 in step S102. For this operation, the level detection unit 45 may detect the output signal V_{out} output from the operational amplifier Amp and then determine the DC voltage level of the output signal V_{out} .
- [58] The control block 40 determines whether the DC voltage level of the input signal V_{in} has reached the reference value V_{BIAS} , with reference to the DC voltage level of the output signal V_{out} , received in step S102, in step S104. According to an embodiment, the reference value V_{BIAS} may be a value previously stored in the control block 40.
- [59] The digital condenser microphone 100 according to the present invention functions as a kind of high-pass filter. When the condenser C_{mic} of the microphone sensor unit 10 has a capacitance of, for example, 1 pF to 10 pF, an input resistor having several hundreds of megaohms to several-gigaohms is required so as to process signals ranging from 20 Hz to 20 kHz in an audio frequency band. When the input resistor is implemented, a Metal Oxide Semiconductor (MOS) transistor in a cut-off region or a

diode has been used in consideration of the area, noise, etc. In the present embodiment, the bias voltage V_{BIAS} is applied to the input signal V_{in} , which has been received from the microphone sensor unit 10 via the first node N_1 , through the MOS transistor or the diode.

- [60] Since the amount of current leaked from a transistor in a cut-off region or a reverse diode is considerably small, it is difficult to measure such a current. Due thereto, it is not easy to form a resistor suitable for the digital condenser microphone 100. Further, the impedance measured at the first node N_1 is not constant due to environmental circuit situations, such as a connection to the microphone sensor unit 10, the layout, a Printed Circuit Board (PCB), temperature, and humidity. In this case, when the impedance is excessively high, the time required for the DC voltage level of the input signal V_{in} , transferred from the microphone sensor unit 10, to converge on the operating region is lengthened due to an increase in time constant.
- [61] The fact that the DC voltage level of the input signal V_{in} has not reached the reference value V_{BIAS} means that the bias voltage V_{BIAS} is not applied to the first node N_1 , that is, the input signal V_{in} , due to the impedance of the impedance unit Z . That is, it means that the total impedance of the impedance unit Z increases, and then the time required for the DC voltage level of the input signal V_{in} , output from the microphone sensor unit 10, to converge on the operating region is lengthened.
- [62] If it is determined that the DC voltage level has not reached the reference value V_{BIAS} (in the case of "No" in step S104), the control block 40 turns on any one of the switches SW_1 to SW_n included in the impedance unit Z in step S106. Until the DC voltage level of the input signal V_{in} reaches the reference value V_{BIAS} , the control block 40 repeatedly performs steps S102 to S106. That is, the control block 40 receives the DC voltage level of the output signal V_{out} from the level detection unit 45 in step S102 until the DC voltage level of the input signal V_{in} reaches the reference value V_{BIAS} , and determines whether the DC voltage level of the input signal V_{in} has reached the reference value V_{BIAS} in step S104. If it is determined that the DC voltage level has not reached the reference value V_{BIAS} , the control block 40 turns on any one switch being in an OFF state among the switches SW_1 to SW_n included in the impedance unit Z in step S106.
- [63] In contrast, if it is determined that the DC voltage level of the input signal has reached the reference value V_{BIAS} (in the case of "Yes" in step S104), the control block 40 turns off the switches SW_1 to SW_n included in the impedance unit Z in step S108. In this way, the switches SW_1 to SW_n are turned off, so that the control block 40 increases the total impedance of the impedance unit Z . That is, the control block 40 maintains the DC voltage level of the input signal V_{in} at the reference value V_{BIAS} .
- [64] Meanwhile, when the operation in step S108 is continuously performed, the total

impedance of the impedance unit Z momentarily or continuously increases. When the total impedance of the impedance unit Z momentarily or continuously increases, the DC voltage level may differ from the reference value V_{BIAS} . When the DC voltage level differs from the reference value V_{BIAS} , the control block 40 may decrease the total impedance by turning on the switches that have been turned off in step S108, either sequentially one by one or simultaneously.

Industrial Applicability

- [65] A digital condenser microphone having a preamplifier with variable input impedance and a method of controlling the variable input impedance of the preamplifier according to the present invention may be effectively used in the field of digital microphones.
- [66] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims. Therefore, the above descriptions and the attached drawings should be interpreted as exemplifying the present invention rather than limiting the spirit of the present invention.

Claims

- [Claim 1] A preamplifier for a digital condenser microphone, comprising:
a bias terminal for applying a bias voltage to an input signal when the input signal is output from a microphone condenser;
an impedance unit including at least one variable input impedance element which is connected to the bias terminal and to which the bias voltage is applied via the bias terminal;
an operational amplifier for receiving the input signal, converting the input signal into an output signal, and outputting the output signal; and
a control block for determining whether a Direct Current (DC) voltage level of the output signal output from the operational amplifier has reached a reference value, and controlling a total impedance of the impedance unit based on a result of the determination.
- [Claim 2] The preamplifier according to claim 1, further comprising a level detection unit for detecting the DC voltage level of the output signal.
- [Claim 3] The preamplifier according to claim 2, wherein the control block is configured to gradually decrease the total impedance of the impedance unit until the DC voltage level of the output signal reaches the reference value.
- [Claim 4] The preamplifier according to claim 2, wherein the control block is configured to maintain or increase the total impedance of the impedance unit if the DC voltage level of the output signal has reached the reference value.
- [Claim 5] The preamplifier according to claim 1, wherein:
the impedance unit comprises a plurality of transistors, and a plurality of switches respectively corresponding to the transistors,
the switches are connected in series with the corresponding transistors, respectively, and
the transistors are connected in parallel with one another and the switches are connected in parallel with one another.
- [Claim 6] The preamplifier according to claim 5, wherein the control block is configured to control the total impedance of the impedance unit by individually controlling ON/OFF operations of the plurality of switches.
- [Claim 7] A preamplifier for a digital condenser microphone, comprising:
an operational amplifier configured to amplify an input signal and output an amplified output signal;
an impedance unit connected to a single input node of the operational

amplifier and configured to vary an impedance thereof; and
a control block configured to receive the output signal from the operational amplifier and then control the impedance of the impedance unit.

[Claim 8] The preamplifier according to claim 7, wherein the control block is configured such that if a Direct Current (DC) voltage level of the output signal output from the operational amplifier has not reached a reference value, the control block gradually decreases the impedance of the impedance unit until the impedance reaches the reference value.

[Claim 9] The preamplifier according to claim 7, wherein the control block is configured such that if a DC voltage level of the output signal output from the operational amplifier has reached a reference value, the control block maintains or increases the impedance of the impedance unit.

[Claim 10] The preamplifier according to claim 7, wherein:
the impedance unit comprises one or more impedance modules,
each of the impedance modules comprises a single transistor and a single switch connected in series with the single transistor, and
the one or more impedance modules are connected in parallel with one another.

[Claim 11] The preamplifier according to claim 10, wherein the impedance unit is configured such that the impedance thereof is controlled in such a way as to apply a bias voltage by turning on the switches included in the respective impedance modules or to cut off the bias voltage by turning off the switches included in the respective impedance modules.

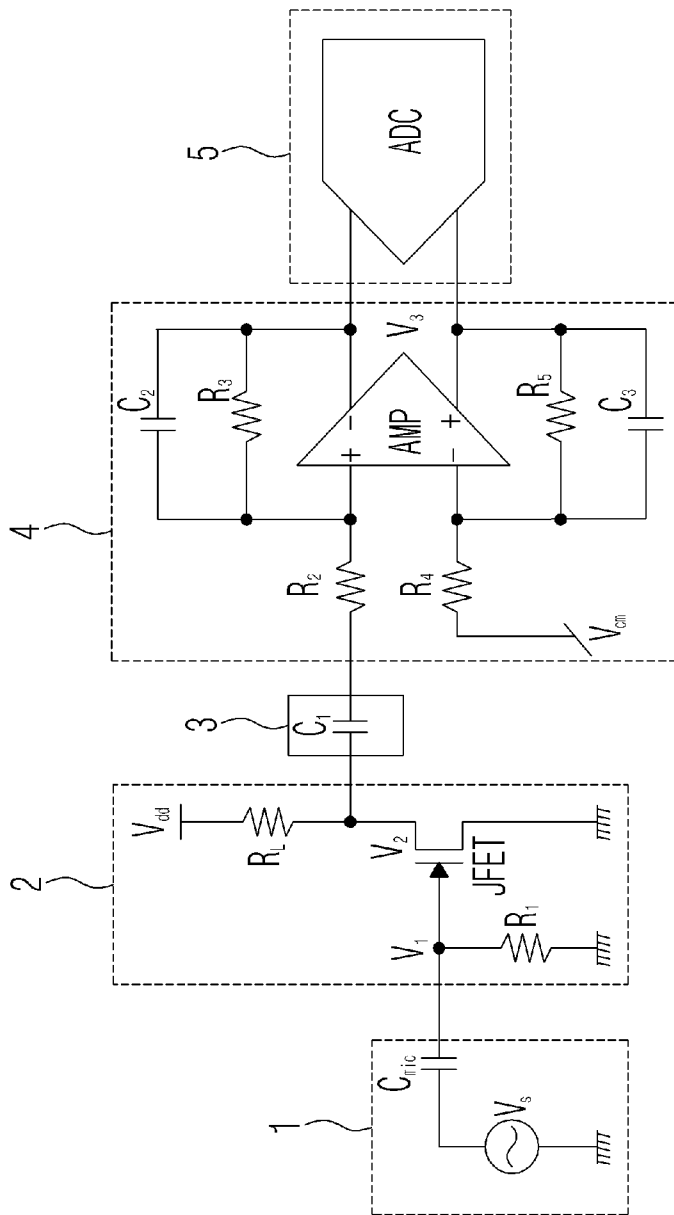
[Claim 12] A digital condenser microphone comprising:
the preamplifier set forth in claim 7;
a microphone sensor unit for converting an externally input acoustic signal into the input signal and outputting the input signal to the preamplifier; and
an Analog to Digital (A/D) converter for receiving an output signal from the preamplifier and converting the output signal into a digital signal.

[Claim 13] The digital condenser microphone according to claim 12, further comprising a level detection unit for detecting a Direct Current (DC) voltage level of the output signal.

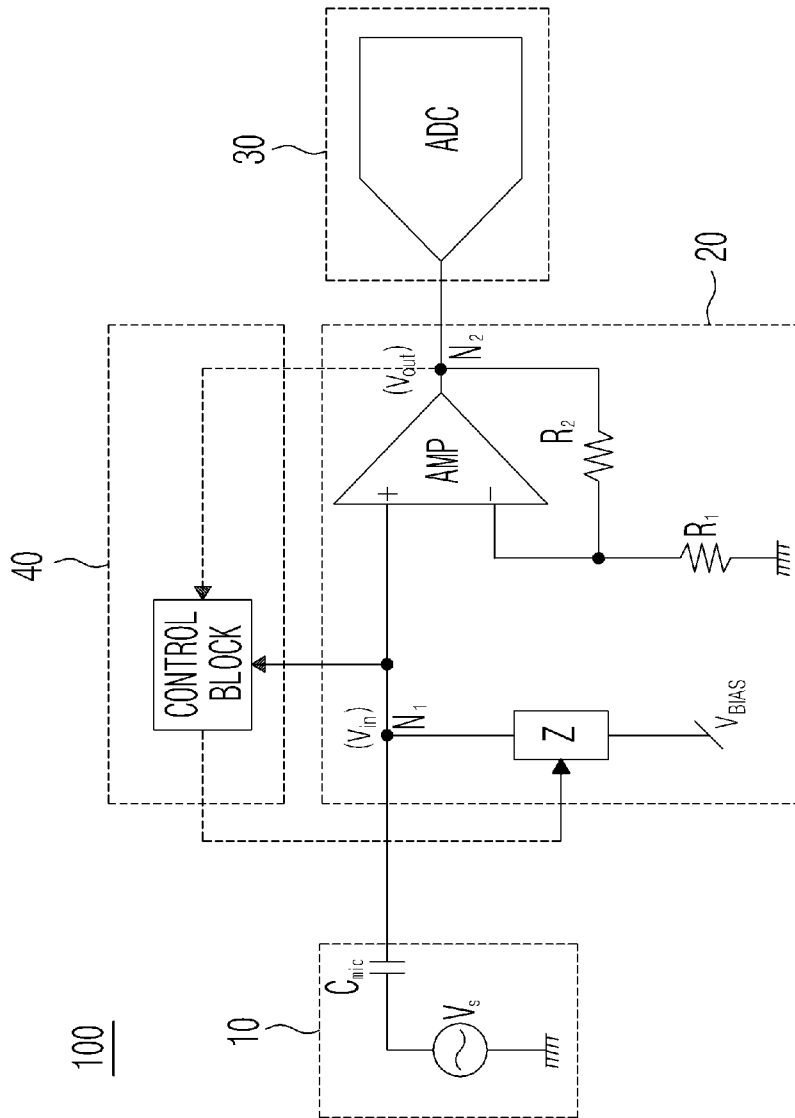
[Claim 14] The digital condenser microphone according to claim 13, wherein the control block is configured to gradually decrease a total impedance of

- the impedance unit until the DC voltage level of the output signal reaches a reference value.
- [Claim 15] The digital condenser microphone according to claim 13, wherein the control block is configured to maintain or increase a total impedance of the impedance unit if the DC voltage level of the output signal has reached a reference value.
- [Claim 16] The digital condenser microphone according to claim 12, wherein: the impedance unit comprises a plurality of transistors, and a plurality of switches respectively corresponding to the transistors, the switches are connected in series with the corresponding transistors, respectively, and the transistors are connected in parallel with one another and the switches are connected in parallel with one another.
- [Claim 17] The digital condenser microphone according to claim 16, wherein the control block is configured to control the total impedance of the impedance unit by individually controlling ON/OFF operations of the plurality of switches.
- [Claim 18] A method of controlling a variable input impedance of a preamplifier for a digital condenser microphone, detecting a Direct Current (DC) voltage level of an output signal output from an operational amplifier; determining whether the DC voltage level has reached a reference value; and if the DC voltage level has not reached the reference value, sequentially one by one turning on switches that have been turned off, among a plurality of switches respectively corresponding to a plurality of transistors included in an impedance unit.
- [Claim 19] The method according to claim 18, further comprising, if the DC voltage level has reached the reference value, turning off the plurality of switches respectively corresponding to the plurality of transistors included in the impedance unit, either sequentially one by one or simultaneously.
- [Claim 20] The method according to claim 19, further comprising, if a comparison between the DC voltage level and the reference value reveals that the DC voltage level has become different from the reference value, turning on the switches that have been turned off, either sequentially one by one or simultaneously.

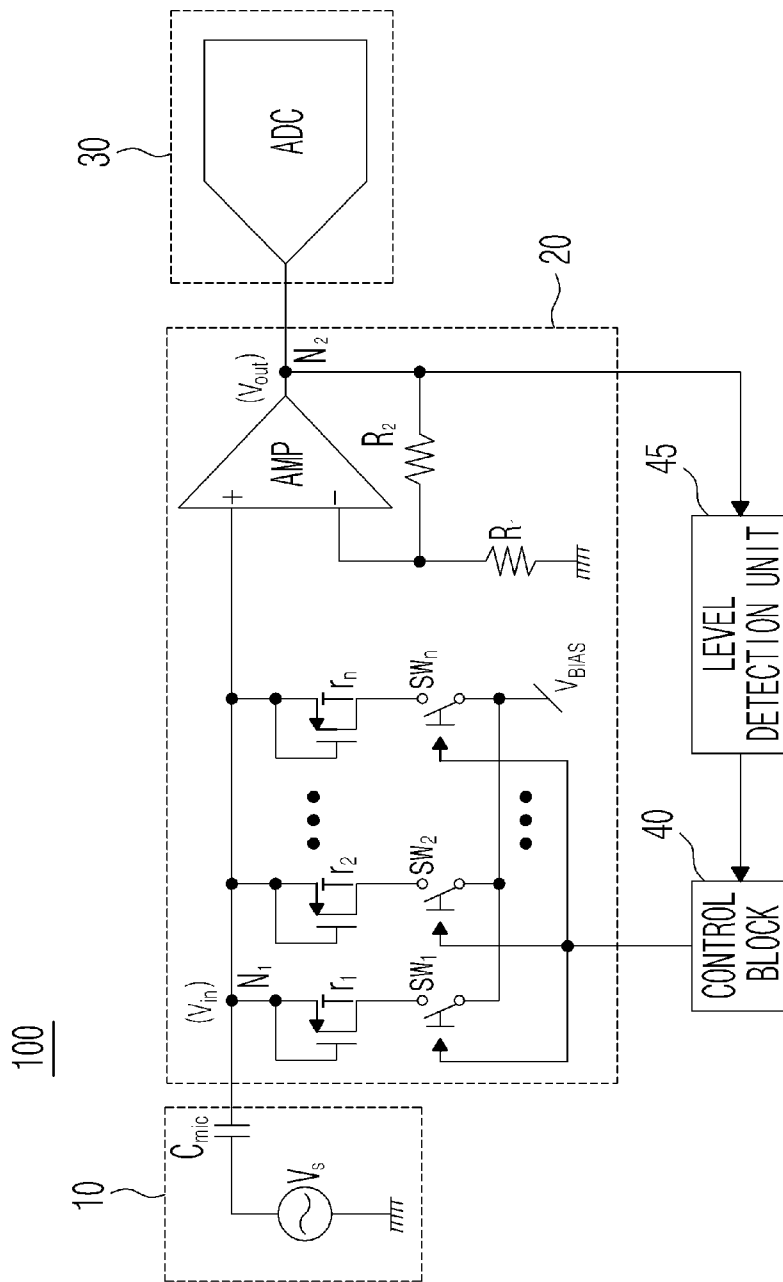
[Fig. 1]



[Fig. 2]



[Fig. 3]



[Fig. 4]

